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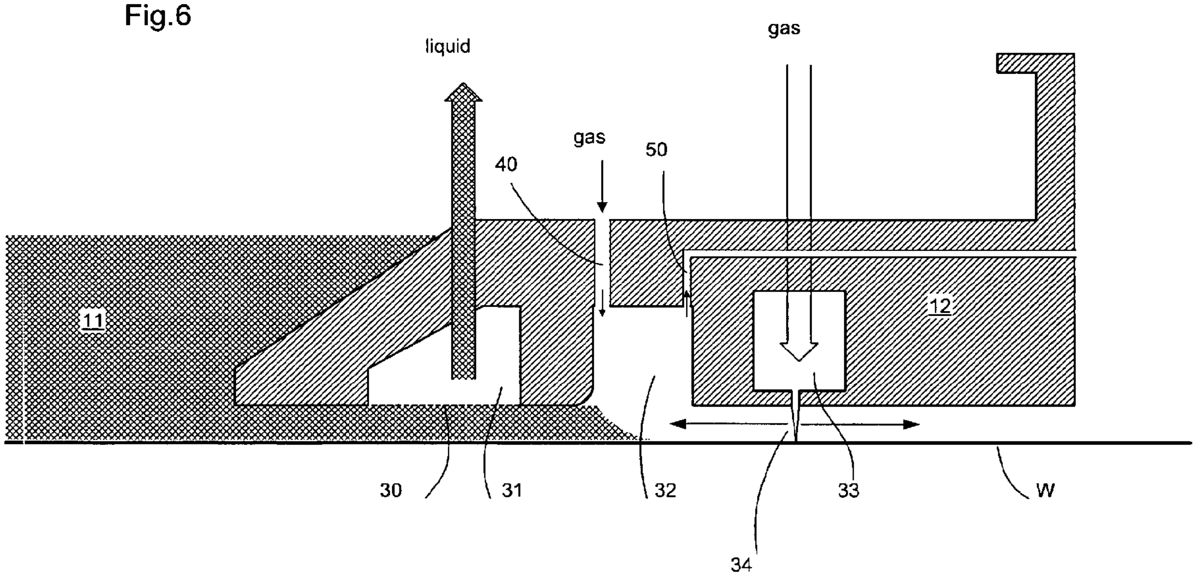
(54) Lithographic apparatus and device manufacturing method

(57) A seal member (12) surrounding a space filled with liquid has a recess (32) in its lower surface which is open to both a relative low pressure source (50) and a relative higher pressure source (40) and through which liquid and/or air from between said seal member and said substrate is extracted.

Fig.6



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Description

Field

[0001] The present invention relates to a lithographic apparatus and a method for manufacturing a device.

Background

[0002] A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g. comprising part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned. Known lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion at one time, and so-called scanners, in which each target portion is irradiated by scanning the pattern through a radiation beam in a given direction (the "scanning"-direction) while synchronously scanning the substrate parallel or anti-parallel to this direction. It is also possible to transfer the pattern from the patterning device to the substrate by imprinting the pattern onto the substrate.

[0003] It has been proposed to immerse the substrate in the lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the final element of the projection system and the substrate. The point of this is to enable imaging of smaller features since the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as increasing the effective NA of the system and also increasing the depth of focus.) Other immersion liquids have been proposed, including water with solid particles (e.g. quartz) suspended therein.

[0004] However, submersing the substrate or substrate and substrate table in a bath of liquid (see for example US 4,509,852, hereby incorporated in its entirety by reference) means that there is a large body of liquid that must be accelerated during a scanning exposure. This requires additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

[0005] One of the solutions proposed is for a liquid supply system to provide liquid on only a localized area of the substrate and in between the final element of the projection system and the substrate using a liquid confinement system (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in WO 99/49504, hereby incorporated in its entirety by reference. As illustrated in Figures 2 and 3, liquid is supplied by at least one inlet IN onto the substrate, preferably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet OUT after having passed under the projection system. That is, as the substrate is scanned beneath the element in a -X direction, liquid is supplied at the +X side of the element and taken up at the -X side. Figure 2 shows the arrangement schematically in which liquid is supplied via inlet IN and is taken up on the other side of the element by outlet OUT which is connected to a low pressure source. In the illustration of Figure 2 the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in- and out-lets positioned around the final element are possible, one example is illustrated in Figure 3 in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element.

[0006] Another solution which has been proposed is to provide the liquid supply system with a seal member which extends along at least a part of a boundary of the space between the final element of the projection system and the substrate table. Such a solution is illustrated in Figure 4. The seal member is substantially stationary relative to the projection system in the XY plane though there may be some relative movement in the Z direction (in the direction of the optical axis). A seal is formed between the seal member and the surface of the substrate.

[0007] Another arrangement is shown in Figure 5. The reservoir 10 forms a contactless seal to the substrate around the image field of the projection system so that liquid is confined to fill a space between the substrate surface and the final element of the projection system. The reservoir is formed by a seal member 12 positioned below and surrounding the final element of the projection system PL. Liquid is brought into the space below the projection system and within the seal member 12. The seal member 12 extends a little above the final element of the projection system and the liquid level rises above the final element so that a buffer of liquid is provided. The seal member 12 has an inner periphery that at the upper end preferably closely conforms to the shape of the projection system or the final element thereof and may, e.g., be round. At the bottom, the inner periphery closely conforms to the shape of the image field, e.g., rectangular though this need not be the case.

[0008] The liquid is confined in the reservoir by a gas seal 16 between the bottom of the seal member 12 and the surface of the substrate W. The gas seal is formed by gas, e.g. air or synthetic air but preferably N_2 or another inert gas, provided under pressure via inlet 15 to the gap between seal member 12 and substrate and extracted via first outlet 14. The overpressure on the gas inlet 15, vacuum level on the first outlet 14 and geometry

of the gap are arranged so that there is a high-velocity air flow inwards that confines the liquid. Such a system is disclosed in European Patent Application No. 03252955.4 hereby incorporated in its entirety by reference.

[0009] In European Patent Application No. 03257072.3 the idea of a twin or dual stage immersion lithography apparatus is disclosed. Such an apparatus is provided with two stages for supporting the substrate. Leveling measurements are carried out with a stage at a first position, without immersion liquid, and exposure is carried out with a stage at a second position, where immersion liquid is present. Alternatively, the apparatus has only one stage.

SUMMARY

[0010] It is desirable to provide an arrangement to remove liquid from the vicinity of the substrate effectively.

[0011] According to an aspect of the invention, there is provided a lithographic projection apparatus arranged to project a pattern from a patterning device onto a substrate using a projection system and having a liquid supply system arranged to supply immersion liquid to a space between the final element of the projection system and the substrate; said liquid supply system comprising:

> a seal member for forming a seal between its lower surface and said substrate thereby substantially to contain said liquid in said space, wherein a recess in said lower surface is open to a first pressure source for extraction of liquid and/or gas and said recess is also open to a second pressure source, said first pressure source being at a lower pressure than said second pressure source such that there is a flow of gas into said first pressure source from said second pressure source.

[0012] According to an aspect of the invention, there is provided a device manufacturing method comprising projecting a patterned beam of radiation onto a substrate using a projection system whilst supplying an immersion liquid to a space between a final element of said projection system and said substrate, and further comprising:

> providing a seal member to contain liquid in said space by removing liquid and/or water from between said seal member and a lower surface of said substrate through a recess in said lower surface, which recess is open to first and second pressure sources, said first pressure source being at a lower pressure than said second pressure source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

- Figure 1 depicts a lithographic apparatus according to an embodiment of the invention;
- Figures 2 and 3 depict a liquid supply system used in a prior art lithographic projection apparatus;
- Figure 4 depicts a liquid supply system according to another prior art lithographic projection apparatus;
- Figure 5 depicts a liquid supply system according to another prior art lithographic projection apparatus; and
- Figure 6 depicts a liquid supply and removal system according to the invention.

DETAILED DESCRIPTION

[0014] Figure 1 schematically depicts a lithographic apparatus according to one embodiment of the invention. The apparatus comprises:

- an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. UV radiation or DUV radiation).
- a support structure (e.g. a mask table) MT constructed to support a patterning device (e.g. a mask) MA and connected to a first positioner PM configured to accurately position the patterning device in accordance with certain parameters;
- a substrate table (e.g. a wafer table) WT constructed to hold a substrate (e.g. a resist-coated wafer) W and connected to a second positioner PW configured to accurately position the substrate in accordance with certain parameters; and
- a projection system (e.g. a refractive projection lens system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

[0015] The illumination system may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

[0016] The support structure supports, i.e. bears the weight of, the patterning device. It holds the patterning device in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The support structure can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device. The support structure may be a frame or a table, for example, which may be fixed or movable as required. The support structure may ensure that the patterning device is at a desired position, for example with respect to the projection system. Any use of

the terms "reticle" or "mask" herein may be considered synonymous with the more general term "patterning device."

[0017] The term "patterning device" used herein should be broadly interpreted as referring to any device that can be used to impart a radiation beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. It should be noted that the pattern imparted to the radiation beam may not exactly correspond to the desired pattern in the target portion of the substrate, for example if the pattern includes phase-shifting features or so called assist features. Generally, the pattern imparted to the radiation beam will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

[0018] The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam which is reflected by the mirror matrix.

[0019] The term "projection system" used herein should be broadly interpreted as encompassing any type of projection system, including refractive, reflective, catadioptric, magnetic, electromagnetic and electrostatic optical systems, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of an immersion liquid or the use of a vacuum. Any use of the term "projection lens" herein may be considered as synonymous with the more general term "projection system".

[0020] As here depicted, the apparatus is of a transmissive type (e.g. employing a transmissive mask). Alternatively, the apparatus may be of a reflective type (e.g. employing a programmable mirror array of a type as referred to above, or employing a reflective mask).

[0021] The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such "multiple stage" machines the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure.

[0022] Referring to Figure 1, the illuminator IL receives a radiation beam from a radiation source SO. The source and the lithographic apparatus may be separate entities, for example when the source is an excimer laser. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is passed from the source SO to the illuminator IL with the aid of a beam delivery system BD comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the lithographic apparatus, for example when the source is a mercury lamp. The source SO and the illuminator IL, together with the beam delivery system BD if required, may be referred to as a radiation system.

[0023] The illuminator IL may comprise an adjuster AD for adjusting the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator IL may comprise various other components, such as an integrator IN and a condenser CO. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section.

[0024] The radiation beam B is incident on the patterning device (e.g., mask MA), which is held on the support structure (e.g., mask table MT), and is patterned by the patterning device. Having traversed the mask MA, the radiation beam B passes through the projection system PS, which focuses the beam onto a target portion C of the substrate W. An immersion hood IH, which is described further below, supplies immersion liquid to a space between the final element of the projection system PL and the substrate W.

[0025] With the aid of the second positioner PW and position sensor IF (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the radiation beam B. Similarly, the first positioner PM and another position sensor (which is not explicitly depicted in Figure 1) can be used to accurately position the mask MA with respect to the path of the radiation beam B, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the mask table MT may be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which form part of the first positioner PM. Similarly, movement of the substrate table WT may be realized using a long-stroke module and a short-stroke module, which form part of the second positioner PW. In the case of a stepper (as opposed to a scanner) the mask table MT may be connected to a short-stroke actuator only, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2. Although the substrate alignment marks as illustrated occupy dedicated target portions, they may be located in spaces between target portions (these are known as scribe-lane alignment marks).

Similarly, in situations in which more than one die is provided on the mask MA, the mask alignment marks may be located between the dies.

[0026] The depicted apparatus could be used in at least one of the following modes:

1. In step mode, the mask table MT and the substrate

table WT are kept essentially stationary, while an entire pattern imparted to the radiation beam is projected onto a target portion C at one time (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed. In step mode, the maximum size of the exposure field limits the size of the target portion C imaged in a single static exposure.

2. In scan mode, the mask table MT and the substrate table WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the mask table MT may be determined by the (de-)magnification and image reversal characteristics of the projection system PS. In scan mode, the maximum size of the exposure field limits the width (in the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion.

3. In another mode, the mask table MT is kept essentially stationary holding a programmable patterning device, and the substrate table WT is moved or scanned while a pattern imparted to the radiation beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device is updated as required after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes programmable patterning device, such as a programmable mirror array of a type as referred to above.

[0027] Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

[0028] Figure 6 shows a water removal device 31 such as the one disclosed in USSN 10/921,348, hereby incorporated in its entirety by reference, in a seal member 12 of an immersion hood IH, according to a particular embodiment of the invention. The liquid removal device 31 comprises a chamber which is maintained at a slight underpressure p_c and is filled with the immersion liquid. The lower surface of the chamber is formed of a thin plate 20 having a large number of small holes, e.g. of diameter d_{hole} in the range of 5 to 50μm, and is maintained at a height h_{gap} in the range of 50 to 300μm above a surface from which liquid is to be removed, e.g. the surface of a substrate W. Perforated plate 20 should be at least slightly hydrophilic, i.e. having a contact angle of less than 90° to the immersion liquid, e.g. water. The liquid removal device 31 is designed substantially for single phase (liquid) extraction. Figure 6 is a cross-sectional view of one side of the seal member 12, which forms a ring around the exposure field of the projection system PL (not shown in Figure 6). The liquid removal device is formed by a ring-shaped chamber 31 near the innermost edge of the underside of the seal member 12. The lower surface of the chamber 31 is formed by a porous plate 30, as described in the above patent application. Ring-shaped chamber 31 is connected to a suitable pump or pumps to remove liquid from the chamber and maintain the desired underpressure. In use, the chamber 31 is full of liquid but is shown empty for clarity.

[0029] Outward of the ring-shaped chamber 31 are a gas extraction ring or recess 32 and a gas supply ring 33. The gas supply ring 33 is a chamber with a narrow slit in its lower part and is supplied with gas, e.g. air, artificial air or flushing gas, at a pressure such that the gas escaping out of the slit forms a gas knife 34. The gas forming the gas (or air) knife is extracted by suitable vacuum pumps connected to the gas extraction ring 32 described below so that the resulting gas flow drives any residual liquid inwardly where it can be removed by the liquid removal device and/or the vacuum pumps, which should be able to tolerate vapor of the immersion liquid and/or small liquid droplets.

[0030] In the apparatus shown in Figure 6, most of the air that forms the air knife is extracted via gas extraction ring 32, but some air may flow into the environment around the immersion hood and potentially disturb the interferometric position measuring system IF. This can be prevented by the provision of an additional gas extraction ring outside the air knife. This also helps by removing water drops on the substrate W or substrate table WT outside (i.e. not under) of the seal member 12. The air knife also functions as an emergency buffer in case the seal member 12 approaches the substrate W too closely.

[0031] Because in this embodiment of the invention, the liquid removal system can remove most of the immersion liquid whilst at a height of 10μm to 1mm, or 50 to 300μm above the surface of the substrate W or the substrate table WT, less onerous requirements are put on the seal member vertical position than when an air bearing is used to confine the immersion liquid. This means that the seal member can be positioned vertically with a simpler actuation and control system. It also means that the requirements on the flatness of the substrate table and substrate are reduced, making it easier to construct devices such as sensors which need to be provided in the upper surface of the substrate table WT.

[0032] The seal member 12 can either be constructed to be fixed relative to the projection system PL or can be arranged to be moveable in the direction of the optical axis and rotatable about the directions perpendicular to the optical axis. One way of arranging for this is for the seal member 12 to bear on the substrate W such that its weight is carried by the substrate W. This can be arranged, for example, by arranging for the gas flow 34 of the air knife to create a force equal and opposite in direction to the force of gravity on the seal member 12.

However, because the area of the recess 32 in the lower surface of the barrier member 12 is larger than the area of the slit through which the air knife 34 exits the seal member 12, any variations in pressure of gas in the recess 32 have a large effect on the force created by that gas on the seal member 12 towards the substrate W. It is therefore desirable to try and minimize pressure fluctuations of gas in the recess 32. This is arranged as described below to prevent the seal member 12 from having a negative stiffness, which could otherwise clamp the seal member 12 to the substrate W.

[0033] As the seal member 12 approaches the substrate W, the force exerted by the negative pressure in the extraction zone of the recess 32 could increase faster than the force exerted by the positive pressure in the gas knife 32 (because the area is bigger) so that the seal member 12 would be driven down towards the substrate W. This can be mitigated by providing, as well as an extraction port 50 which is connected to a low pressure source, an ambient port 40 which is open to a relatively higher pressure source such as the ambient atmosphere. In this way gas enters through the port 40 to take the place of gas and/or liquid which exits through extraction port 50. Thus, it is arranged that there is always a flow of gas through the ambient port 40 so that pressure fluctuations, which change with the distance between the seal member 12 and substrate W, are reduced.

[0034] The water removal device 31 and the relative pressures of gas in chamber 33 and recess 32 (which is controlled by the relative pressures of gases at the ambient and extraction ports) are adjusted to prevent the immersion liquid 11 meniscus being dragged radially inwardly towards the exposure field (on the left hand side of Figure 6) by movement of the substrate W. Indeed, it is preferred that the liquid removal system 31 removes only liquid and no gas such that the meniscus of the liquid 11 is positioned under the recess 32. To arrange for this flow restrictions or other means can be used to adjust the relative pressures of the gas source to which the ambient port 40 is connected and the pressure of the relative low pressure source o which the extraction port 50 is connected. A level of-20 to -10 mbar gauge in the recess 32 has been found to be optimal though a range of from -50 to +100 mbar gauge is a possible working range. If the relative low pressure source is at a pressure in the range from - 50 to -500 mbar gauge or -50 to -200 mbar gauge, the ambient port may be open to the atmosphere to achieve the desired pressure in the recess 32.

[0035] With this arrangement a flow of gas out of the gas knife 34 is created both radially inwardly towards the recess 32 and radially outwardly towards the radially outer edge of the seal member 12. The gas flow travelling radially inwardly from the gas knife 34 to the recess 32 helps the maintain the position of the liquid meniscus substantially under the recess 32 and gas and/or liquid are extracted through extraction port 50. Gas is also drawn into the recess through ambient port 40 thereby to avoid pressure fluctuations in the recess 32 when there is a change in height of the seal member 12 above the substrate W or a change in flow conditions of either the gas coming from the gas knife 34 or of liquid coming from the space between the final element of the projection system and the substrate W.

[0036] It has been found that positioning the ambient port 40 radially inwardly of the extraction port 50 is optimal and these ports are preferably positioned in a top surface of the recess 32 opposite the side of the recess 32 which is open to the bottom surface of the seal member 12 which faces the substrate W. The ambient port 40 and extraction port 50 may be circular grooves (in the same way that recess 32 is a circular or other loop shaped shape) or those ports may be a plurality of discreet holes in the top surface of the recess 32.

[0037] Below some operating conditions for the various components of the seal member 12 are given. The pressures mentioned are gauge. Therefore the pressure of the relative higher pressure source to which the ambient port 40 is connected is 0 mbar. The relative lower pressure source to which the extraction port 50 is connected is about -100 mbar. It is preferred that this extractor is for gas only because it has been found that removing a mixture of gas and liquid can lead to undesirable vibrations.

[0038] The gas in chamber 33 is at a pressure of about 800 mbar and is humidified gas thereby to minimize evaporation and thereby cooling of the substrate W though the gas is not necessarily humidified. A typical gas flow rate of 100 litre/min is used and again the gas knife 34 may be provided through an annular continuous cavity or through a plurality of discreet holes. A gas flow rate of about 50 litre/min through the extraction port 50 is envisaged and a gap between the bottom of the seal member 12 and the substrate W is approximately 100 μm (preferably in the range 80 to 130 μm).

[0039] Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "wafer" or "die" herein may be considered as synonymous with the more general terms "substrate" or "target portion", respectively. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist), a metrology tool and/or an inspection tool. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already contains multiple processed lay-

ers.

[0040] The terms "radiation" and "beam" used herein encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. having a wavelength of or about 365, 248, 193, 157 or 126 nm).

[0041] The term "lens", where the context allows, may refer to any one or combination of various types of optical components, including refractive and reflective optical components.

[0042] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. For example, the invention may take the form of a computer program containing one or more sequences of machine-readable instructions describing a method as disclosed above, or a data storage medium (e.g. semiconductor memory, magnetic or optical disk) having such a computer program stored therein.

[0043] The present invention can be applied to any immersion lithography apparatus, in particular, but not exclusively, those types mentioned above. The immersion liquid used in the apparatus may have different compositions, according to the desired properties and the wavelength of exposure radiation used. For exposure wavelength of 193nm, ultra pure water or water-based compositions may be used and for this reason the immersion liquid is sometimes referred to as water and water-related terms such as hydrophilic, hydrophobic, humidity, etc. may be sued. However it is to be understood that the present invention may be used with other types of liquid in which case such water-related terms should be considered replaced by equivalent terms relating to the immersion fluid used.

[0044] The descriptions above are intended to be illustrative, not limiting. Thus, it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

Claims

1. A lithographic projection apparatus arranged to project a pattern from a patterning device onto a substrate using a projection system and having a liquid supply system arranged to supply immersion liquid to a space between the final element of the projection system and the substrate; said liquid supply system comprising:

   a seal member for forming a seal between its lower surface and said substrate thereby substantially to contain said liquid in said space, wherein a recess in said lower surface is open to a first pressure source for extraction of liquid and/or gas and said recess is also open to a second pressure source, said first pressure source being at a lower pressure than said second pressure source such that there is a flow of gas into said first pressure source from said second pressure source.

2. The apparatus of claim 1, wherein said seal member surrounds said space.

3. The apparatus of claim 2, wherein said recess forms a closed loop around said space.

4. The apparatus of claim 1, 2 or 3, wherein a gas jet is positioned radially outwardly of said recess.

5. The apparatus of claim 4, wherein said gas jet creates a flow of gas between said seal member and said substrate radially inwardly into said recess.

6. The apparatus of claim 4 or 5, wherein said gas jet is produced by allowing gas to exit a chamber in which gas is contained at from 200 to 2000 mbar gauge.

7. The apparatus of any one of the preceding claims, wherein a liquid removal device is positioned radially inwardly of said recess.

8. The apparatus of claim 7, wherein said liquid removal device is arranged substantially to remove only liquid.

9. The apparatus of any one of the preceding claims, wherein said first pressure source and said second pressure source are positioned in said recess opposite the opening of said recess in said lower surface.

10. The apparatus of any one of the preceding claims, wherein an inlet into said recess of said first pressure source is positioned radially outwardly of an inlet into said recess of said second pressure source.

11. The apparatus of any one of the preceding claims, wherein gas in said recess is arranged to be at a pressure in the range of from +100 to -50 mbar gauge.

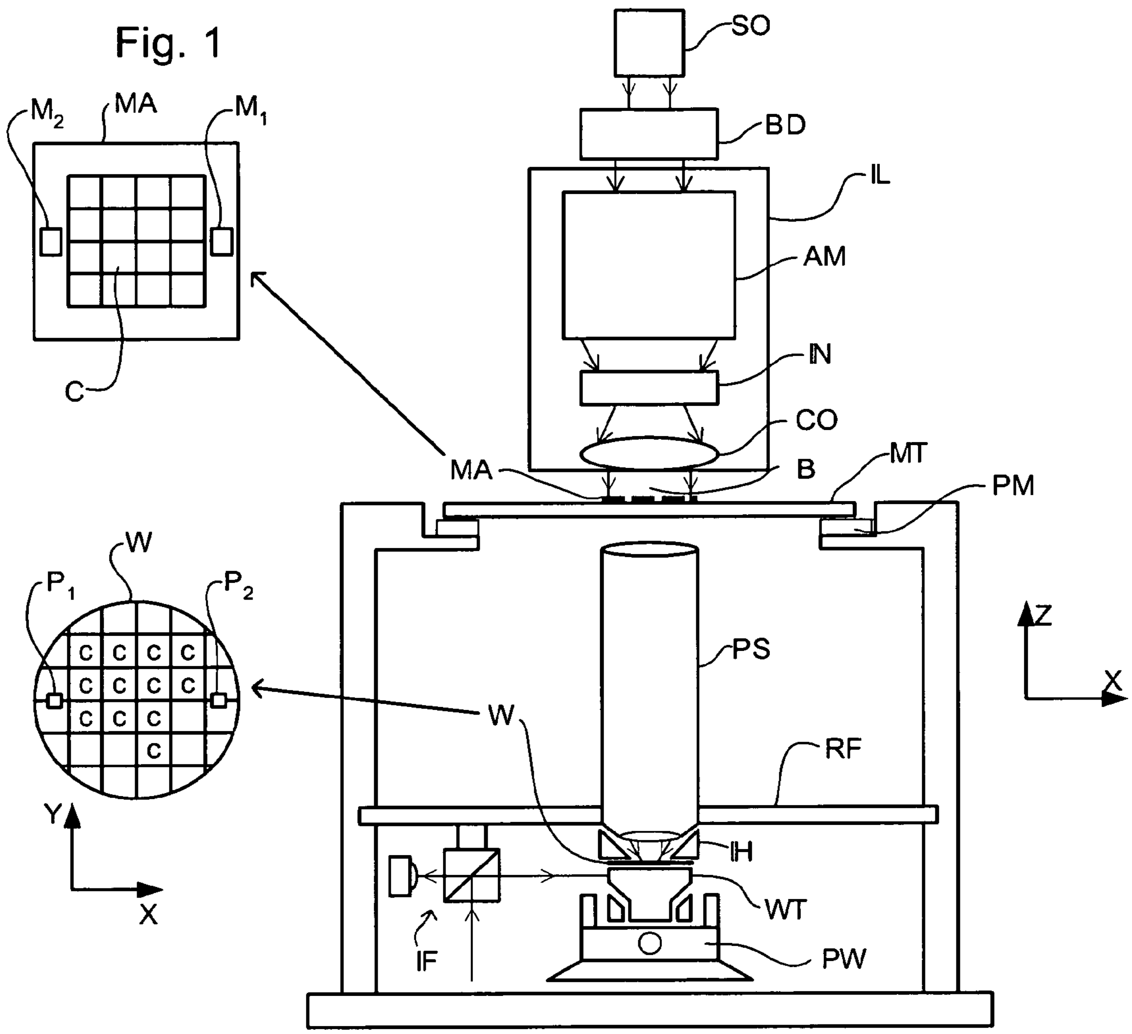
12. The apparatus of any one of the preceding claims, wherein gas in said first pressure source is at a pressure of from -50 to -500 mbar gauge.

13. The apparatus of claim 1 or 2, wherein, in plan, said space is smaller in area than said substrate.

14. A device manufacturing method comprising projecting a patterned beam of radiation onto a substrate using a projection system whilst supplying an immersion liquid to a space between a final element of said projection system and said substrate, and further comprising:

providing a seal member to contain liquid in said space by removing liquid and/or water from between said seal member and a lower surface of said substrate through a recess in said lower surface, which recess is open to first and second pressure sources, said first pressure source being at a lower pressure than said second pressure source.

Fig. 1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BD
IL
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IN
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M2
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M1
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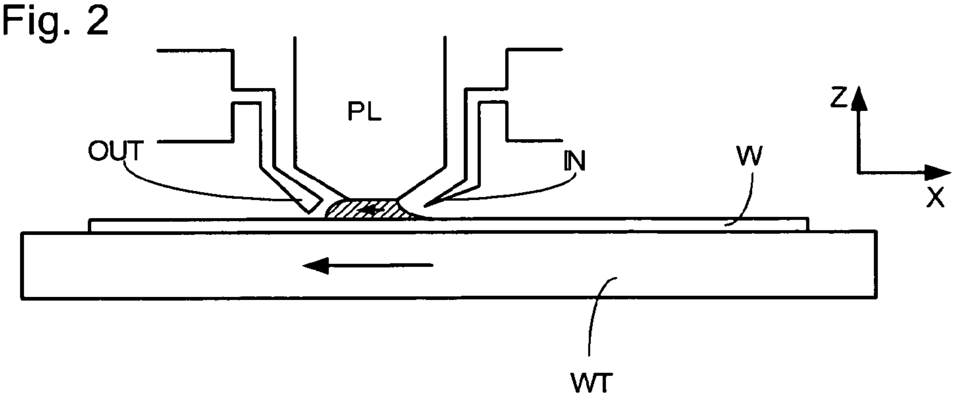
Fig. 2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OUT
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WT

Fig. 3

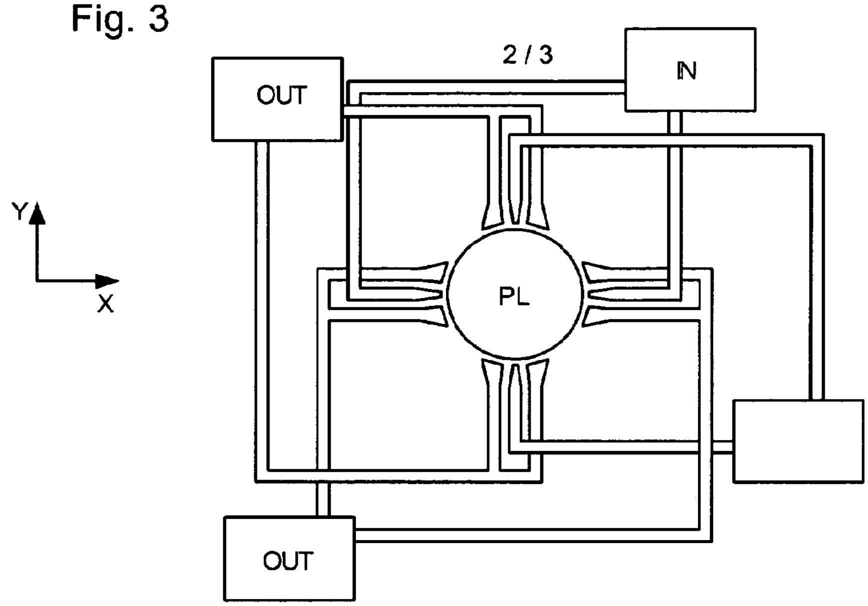


Fig. 4

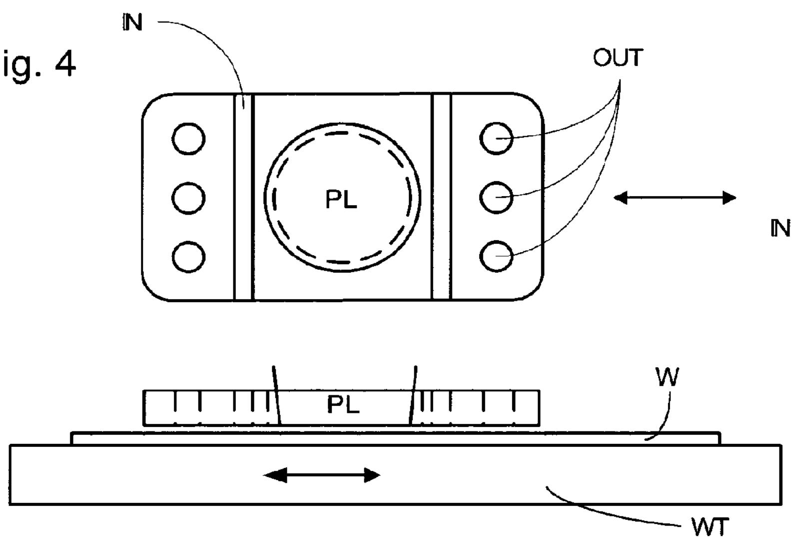
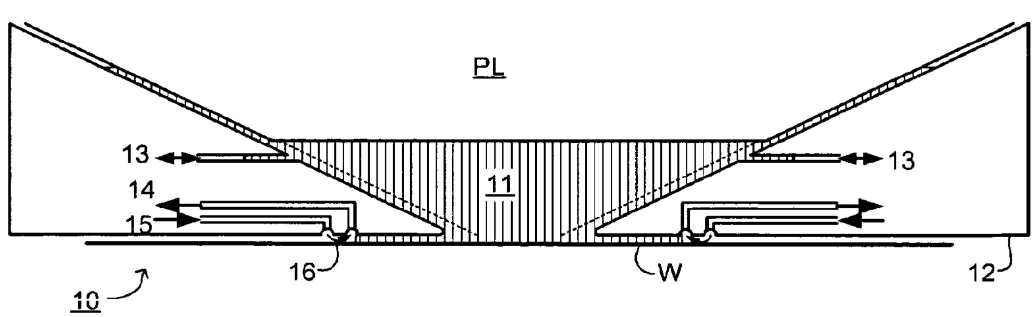


Fig. 5



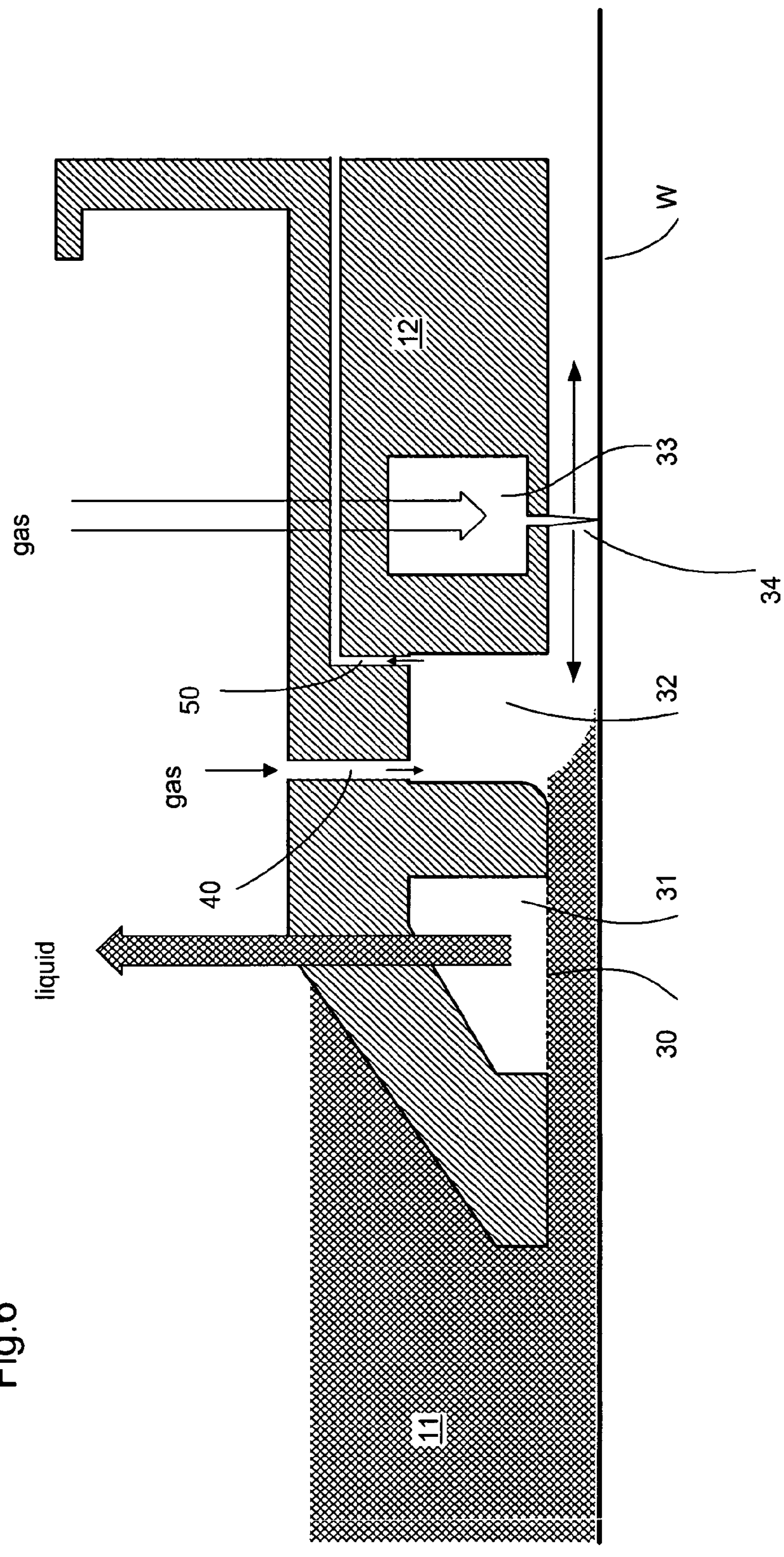


Fig.6